

## **2. Distribution Module**

The Distribution Module addresses the portion of the network extending from SAIs to the customers' premises. The module determines the lengths and sizes of distribution cable, the associated structures (poles and trenching), and the number of terminals, splices, drops, and Network Interface Devices (NIDs) required to provide service to the specified number and type of customers in each CBG. Once it has determined the amount of all distribution elements required, it calculates the investment associated with these elements, using inputs on the unit prices of each such element. It provides these investments to the Feeder Module. The numbers and types of elements engineered can also be examined in the intermediate outputs of the Distribution Module.

## **3. Feeder Module**

The Feeder Module configures the portion of the network that extends from the wire center to the SAIs. The module chooses whether to serve a CBG using feeder transmission facilities consisting of copper wire pairs or digital loop carrier (DLC) running over fiber optic cable. The selection is made according to a user-adjustable parameter that specifies the maximum feeder distance to the CBG beyond which fiber is to be installed. Following this selection, it determines the length and size of cables required to reach the SAIs located in each CBG, along with all associated components, such as the SAI enclosures, DLC terminals, and supporting structures (cabinets, poles, trenching, conduit, and manholes). Once it has determined the amount of all feeder elements required, it calculates the investment associated with these elements, using as inputs the unit prices of each such element. It provides these investments to the Expense Module. The numbers and types of elements required can also be examined in the intermediate outputs of the Feeder Module.

## **4. Switching and Interoffice Module**

The Switching and Interoffice Module computes investments for end office switching, tandem switching, signaling, and interoffice transmission facilities. It determines the required line, traffic, and call processing capacity of switches based on line totals by customer type across all CBGs served by

the wire center, and on ARMIS-derived traffic and calling volume inputs. It also determines the required capacity and distances of interoffice transmission facilities, using the traffic data and the interoffice distances that are input to the Module. These investments are provided to the Expense Module. The numbers and types of elements involved can also be examined in the intermediate outputs of the Switching and Interoffice Module.

HM3.0 derives its switch investment estimates based on data describing typical per-line prices paid by BOCs, GTE and other independents,<sup>15</sup> and data from Table 2.10 of the FCC's *Statistics of Communications Common Carriers*. This source provides the average number of access lines served by existing LEC switches.

## 5. Expense Module

The Expense Module calculates the monthly costs for unbundled network elements, universal service and carrier access. These costs include both capital carrying costs associated with the investments, and the costs of their operation. Capital carrying costs include depreciation, return on the debt and equity investment required to build the network, and income taxes on equity return. Network related expenses include maintenance and network operations. Non-network related expenses include customer operations expenses, general support expenses, other taxes and variable overhead expenses.

Information used in developing these monthly costs is obtained from three sources. Network investments by specific plant category are provided by the Distribution, Feeder, and Switching and Interoffice Modules. Information on network operating and maintenance expenses is derived from ARMIS, and other sources.

The Expense Module produces reports showing the key outputs of the model, including the costs of providing universal service, unbundled network elements, and carrier access. Results may be displayed by density zone or individual wire center. These outputs are based on investments calculated at the CBG level.

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<sup>15</sup> See U.S. *Central Office Equipment Market -- 1994*, McGraw-Hill.

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## IV. MODULE DESCRIPTIONS

### A. WORK FILES

Work files contain four categories of information, as follows.

#### 1. Demographic and geological parameters

Demographic and geological parameters are obtained from a database developed by PNR and Associates of Jenkintown, PA. This database was created in the following fashion.

PNR's estimates of residential lines per CBG are based on the number of households in each CBG, using 1995 census estimates provided by Claritas and current Donnelley Marketing household data. These household counts were adjusted to reflect first and second telephone line penetration rates. The percent of households without telephones was obtained from the 1990 Census for every CBG. Second residential lines were estimated as functions of CBG demographic information. The results were projected to every CBG in the US using census age and income distributions, and to every Census Block (CB) within a CBG using census household data at the CB level.

PNR geo-coded the entire Donnelley DQI database of approximately 85 million household street addresses and telephone numbers with latitude/longitude values and their CB codes. A correspondence table was created to link each CB to an appropriate wire center based on telephone number NPA-NXX. When multiple wire centers served a CB, the wire center serving the plurality of households was selected. The total computed number of residential access lines at the state level is to be constrained to be consistent with the number of residential access lines reported by the ILEC to the FCC.

Business lines, including Centrex lines, were estimated by PNR through the use of a business line model. This model used customer survey results combined with information on Standard Industry Codes(SIC), number of employees, region, and legal status to develop detailed telecommunications-use profiles for all business categories considered in the model. The results of this model were then used to estimate the number and types of business lines for each firm listed in the Dun & Bradstreet (D&B) database.

Business establishments in the D & B database were then geo-coded

with longitude/latitude codes and assigned to their respective CBGs. Using the CB to wire center correspondence table, the number of access lines of each firm within a CB or CBG was aggregated to obtain an estimate of the total number of business access lines within each wire center. The total number of business access lines, including Centrex lines, at the state level, is to be constrained to be consistent with the number of business access lines reported to the FCC.

Data within the resulting database are organized by state. Each state file contains a list of that state's (CBGs)<sup>16</sup>. Each CBG appears as a separate record in a Microsoft Excel 7.0 spreadsheet containing the following information:

- Assignment of the CBG to an ILEC wire center based on the most prevalent assignment of area code and central office code (NPA-NXX) combination assigned to premises in that CBG. If the CBG would be assigned to a wire center that exceeds 10Kft in distance and is 150 percent more distant than the nearest wire center, the CBG is reassigned to the nearest wire center.
- The identity of the ILEC owning the wire center serving the CBG;
- The angle (relative to East) and radial distance of the CBG from its serving wire center;
- The number and type (single family detached homes, multi-tenant units of various sizes, mobile homes, etc.) of housing units, with household counts based on the 1995 census update;
- The number of businesses and business employees;
- The total number of business, residence, public and special access lines based on PNR analysis of census data, Dun & Bradstreet business data that reflects the type of businesses located in the CBG, and LEC ARMIS data on the total number of lines of each category served;
- The percentage of the CBG's land area that is unoccupied; and
- geological parameters that indicate bedrock depth, bedrock hardness, soil type, and water table depth.

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<sup>16</sup> Appendix C provides a more detailed description of this process

A more complete description of these data and the sources and processes used to develop them is contained in Appendix A to this document.

## **2. Interoffice distances**

Calculations required to determine total route-miles of interoffice facilities require as inputs the distances between each LEC end office and the tandem switch that is assumed to serve it, the distance between the EO and the STP pair that serves it, distances between STPs, and distances between tandem offices. These data are calculated from a database licensed from Bellcore containing information from the Local Exchange Routing Guide (LERG).

## **3. ARMIS data reported by the LECs**

Access line demand data is obtained from the ARMIS 43-08 Operating Data Reports, submitted to the FCC annually by all Tier 1 LECs.<sup>17</sup> HM3.0 incorporates the following data from this source:

- Analog and digital residential access lines. These totals measure all residential switched access lines, including flat rate (1FR) and measured rate (1MR) service;
- Business access lines, including analog single business lines, analog multiline business lines and digital business lines. These totals include flat rate business (1FB) and measured rate business (1MB) single lines, PBX trunks, Centrex lines, hotel/motel long distance trunks and multiline semi-public lines;<sup>18</sup>
- Analog and digital special access lines. These totals include dedicated lines connecting end users' premises to an IXC POP, but do not include intraLATA private lines; and
- Public access lines, which include lines associated with coin (public

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<sup>17</sup> See, Reporting Requirements for Certain Class A and Tier 1 Telephone Companies (Parts 31, 43, 67 and 69 of the FCC's Rules), CC Docket No. 86-182, 2 FCC Rcd 5770 (1987) (ARMIS Order), modified on recon., 3 FCC Rcd, 6375 (1988). Tier 1 LECs are those with more than \$100 million in annual revenues from regulated services. This includes over 50 carriers.

<sup>18</sup> *Id.* at 1-2.

and semi-public) phones, but exclude customer owned pay telephone lines.<sup>19</sup>

#### **4. User inputs**

This category comprises user-definable values, ranging from the price of network components to the percentage of joint-use end offices and tandem offices, to capital structures. HAI and its clients have supplied default values for each of these parameters based on their collective judgment, as augmented by subject matter experts in various areas of network technology, operations and economics. Users can vary these default parameters to reflect local conditions. Appendix B contains a complete description of these parameters, along with the default values that have been assigned to them.

### **B. COMMON ASPECTS OF THE DISTRIBUTION MODULE AND THE FEEDER MODULE**

Within the Hatfield Model, two separate modules address the development of investments in distribution and feeder facilities. These are discussed in Sections C and D below. This section describes those elements that are common to both.

#### **1. General Outside Plant Configuration**

In configuring the outside plant portion of the local loop, the Hatfield Model duplicates procedures followed by outside plant planning engineers using the Long Range Outside Plant Planning Process (LROPP). In a classic LROPP analysis, the loop is segmented into Distribution Plant and Feeder Plant. The two segments are connected by a feeder-distribution interface, called a Serving Area Interface (SAI). Distribution plant is configured in Distribution Areas.

#### **2. Basic Assumptions**

The following assumptions are common to both the distribution and feeder

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<sup>19</sup> *Id.* at 2.

modules. They are fully consistent with current network engineering models and conventions.

- CBGs are square.
- Wire centers serve a discrete set of CBGs, and each CBG is served by one wire center.<sup>20</sup>
- All distribution cable is copper. Feeder cable can be either copper or fiber, depending on a set of criteria discussed in Section D.

### **3. Lines Density Considerations**

The lines density of each CBG, as measured by lines per square mile, determines the fill factors for distribution and feeder copper cable, and the mixture of underground, buried and aerial plant. There are nine density groupings.

<b>Density Ranges (lines/sq. mile)</b>
0-5
5-100
100-200
200-650
650-850
850-2,550
2,550-5,000
5,000-10,000
10,000+

<sup>20</sup> This assumption may mean that costs are overestimated because some potential efficiencies are missed, but a cost model cannot fully replicate the detailed network engineering processes that could exploit all such efficiencies.

#### 4. Outside Plant Structure

Outside plant structure refers to the set of facilities that support, house, guide, or otherwise protect distribution and feeder cable. There are three types of structure: aerial, buried, and underground.

##### a. Aerial Structure

Aerial structure consists of poles. Pole investment is a function of the material and labor costs of placing a pole. There is a user-adjustable input that can customize labor rates to local conditions. The Hatfield Model computes the total investment in aerial distribution and feeder structure within a CBG by evaluating relevant parameters, including the distance between poles, the investment in the pole itself, the total cable sheath mileage, and the fraction of aerial structure along the route.

Poles are assumed to be 40 foot Class 4 poles. The spacing between poles for aerial cable is fixed within a given density range, but may vary between density ranges. The number of poles on a given run is calculated as

$$1 + (\text{route distance} / \text{pole spacing}), \text{rounded up.}$$

##### b. Buried Structure

Buried structure consists of trenches and related protection against water and other intrusions. The additional cost for protective sheathing of buried cable is a fixed amount per foot in the case of fiber cable, and is a multiplier of cable cost in the case of copper cable.<sup>21</sup> The total investment in buried structure is a function of total route mileage, the fraction of buried structure, investment in protective sheathing and the density range-specific cost of trenching. A user-adjustable input can be used to modify the labor rates used in these calculations to reflect local conditions.

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<sup>21</sup> The default values for sheathing are \$.20 per foot for fiber and a multiplier of 1.04 for copper. The different treatment reflects the fact that the outside dimension of fiber cable is relatively fixed for different strand numbers, while the dimension of copper cable increases with the number of pairs.

### c. Underground Structure

Underground structure consists of conduit and, for feeder plant, manholes and fiber pullboxes. Manholes are used in conjunction with copper cable routes; pullboxes are used with fiber routes. The total investment in a manhole varies by density zone and is a function of the following investments: materials, frame and cover, excavation, backfill, and site delivery. Investment in fiber pullboxes is a function of materials and labor. Underground cables are always housed in conduit facilities that extend between manholes or pullboxes. The total investment in underground structure is a function of total route mileage, the fraction of underground structure, investment in conduit and investment in manholes or pullboxes.

In each line density range, there may be a mixture of aerial, buried, and underground structure. The breakdown may vary by density range, due to the factors that are more likely to be prevalent in certain areas. For example, in downtown urban areas it is frequently necessary to install cable in underground conduit systems, while rural areas may accommodate less expensive aerial or direct-buried plant. Suburban areas may have a mixture of each.

Users can adjust the mix of aerial, underground and buried cable assumed within the Hatfield model. These settings may be made separately within each density zone for fiber feeder, copper feeder, and copper distribution cables. A detailed list of the Hatfield Model structure default values for aerial, buried and underground plant is included in Appendix B.

## 5. Terrain and Placement

The Hatfield Model incorporates the effects of geological factors on required structure investment. Terrain factors considered by the model include:

- Depth to bedrock;
- Hardness of bedrock; and
- Surface soil texture.

If the actual rock depth in a CBG is less than a user-definable rock depth threshold, a rock placement multiplier is used to increase structure investment in poles, conduit and trenching.<sup>22</sup> This is done because it is more difficult to bury cable in rock than in soil.

If bedrock is below the placement depth, then the surface soil texture is examined to determine if soil can be plowed, or if more expensive placement techniques must be used. Certain kinds of soil may increase the cost of structure. When these soils are encountered, the computed distribution distances are increased 20 percent over what they would have been absent the problem. This is based on the assumption that difficult soil conditions will either require cable to be placed along alternative, presumably longer, routes, or will increase installation costs for placing cable in those difficult areas. If both difficult soil conditions and shallow bedrock are encountered, the model will add both the distance and increase the installation cost through the use of the placement multiplier.

Copper buried plant requires protection against water intrusion, at an additional cost. For copper cable, the additional cost is treated as a multiplier of cable cost, since the both cable size and the amount of protective material required grow with the number of pairs.

Labor costs for placement may be regionalized through the application of a user-entered factor.

## **6. Structure Sharing**

Outside plant structures are generally shared by LECs, CATV operators, electric utilities, and others including competitive access providers (CAPs) and IXC's. To the extent that several utilities may place cables in common trenches, or on common poles, it is appropriate to share the costs of these structure items among them. The Hatfield model assumes structure costs are shared among the various utilities that occupy the structure. Although assumptions concerning the degree of sharing are user-adjustable; the default values used in the Hatfield Model reflect best forward-looking, economic practices of the various utilities involved.

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<sup>22</sup> The Hatfield Model default values for geological factors are as follows: rock depth threshold - 24 inches; hard rock placement multiplier - 3.5; and soft rock placement multiplier - 2.0.

## **C. DISTRIBUTION MODULE**

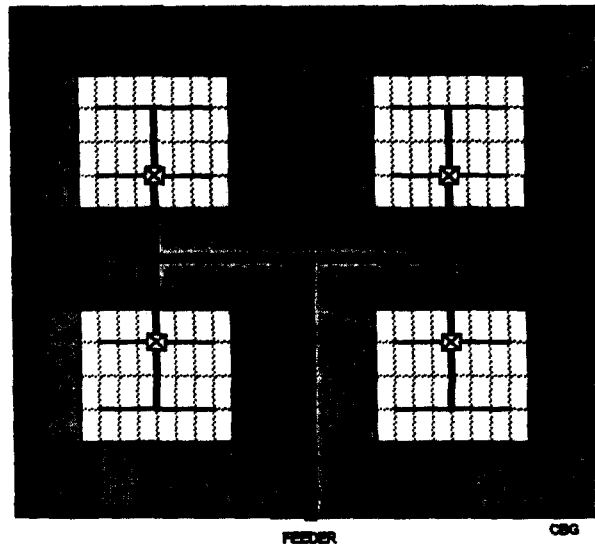
### **1. Overview**

The basic distribution architecture employed by the Hatfield Model is depicted in Figure 5 below. The areas are treated with the distribution grid shown in Figure 5. That is,

- backbone distribution cables begin at the SAI location and extend vertically to within one lot depth of the top and bottom CBG boundary; and
- branches spaced two lot depths apart traverse the CBG horizontally to within one lot width of the left and right CBG boundaries, creating the typical "pine tree", or "tree and branch" topology.

The distribution facilities are assumed to consist of cable containing copper wire pairs in sufficient numbers to meet the demand in the area being served. Adequate provisions for reserve capacity is assured by the conservative distribution fill factor. Thus, for example, if a backbone cable must serve 75 lines with a fill factor of 50%, then the cable is initially sized as 75 pairs divided by 0.5, or 150 pairs. The model will, however, use the next available cable size, which in this case is 200 pairs.

At a point close to a given customer's location, a splice and terminal are installed to separate out one or more wire pairs from the distribution cable, and connect them via an aerial or buried drop to the NID located on the wall of the premises. The residential drop and NID have a two-pair capacity to provide for a second line into the home; business drops and NIDs are assumed to have a four-line capacity.



**Figure 5 Distribution Architecture**

Hatfield Model default values for the relative amounts of aerial, buried, and underground are displayed in the following table

Copper distribution Type Breakdown			
Density Range	Aerial Fraction	Buried Fraction	Underground Fraction
0 - 5	.25	.75	-
5 - 100	.25	.75	-
100 - 200	.25	.75	-
200 - 650	.30	.70	-
650 - 850	.30	.70	-
850 - 2,550	.30	.70	-
2,550 - 5,000	.30	.65	.05
5,000 - 10,000	.60	.35	.05
>10,000	.85	.05	.10

Note: Aerial Fraction includes Block & Building Cable

## **2. Distribution Plant Calculations**

The following steps are performed to determine the appropriate distribution plant based on the demographic and geographic data of the CBG:

1. The CBG is divided into quadrants.
2. Each quadrant's area is reduced uniformly by the percent of the CBG that is empty, (obtained from the PNR database).
3. CBGs that have a total area less than .03 square miles and a lines density higher than 30,000 lines per square mile are identified as high-rise CBGs. Specific high-rise calculations are applied to determine the cost of distribution for these CBGs.
4. Lot size per customer location is calculated (with an adjustment for multidwelling units)
5. For density zones 4-9 that have <50% empty area, a cluster is formed in each quadrant. The size of the clusters is calculated using the average lot size per customer location, with a maximum lot size of three acres. Distribution grid calculations are applied to the clusters.
6. For density zones 1-3 with <50% percent empty, 85% of the customer locations are assumed to be clustered in the center of each of the four quadrants. The size of the cluster is calculated using the average lot size per customer location, with a maximum lot size of three acres. Distribution grid calculations are applied to the clusters. The remaining 15% of the customer locations are assumed to not be located in grids and are served by extending distribution cable along calculated lot frontage.
7. For density zones 1-3 with >50% percent empty, 85% of the customer locations are assumed to be clustered in the center of two of the quadrants. The size of the cluster is calculated using the average lot size per customer location, with a maximum lot size of three acres. Distribution grid calculations are applied to the clusters. The remaining 15% of the customer locations are assumed to not be located in grids and are served by extending distribution cable along calculated lot frontage.

a) Unoccupied Land and Clustering

The PNR database for each CBG specifies the amount of unoccupied land belonging to each CBG, expressed as a fraction of the total land area of the CBG. PNR derived this information by analyzing the occupancy of the census blocks that make up the CBGs.

The model divides the CBG into four quadrants. Each cluster is centered on the middle point of the quadrant in which it is located. This creates an overall "window pane" effect in which there is empty space both in the middle of the CBG extending vertically and horizontally from the SAI and at the edges of the CBG.

A further refinement is undertaken for the lowest three density zones. If the effective lot size in the clusters, as discussed subsequently, exceeds three acres, the model assumes that customers are not distributed uniformly throughout the cluster, and that there is further concentration within each cluster. The model assumes a "sub-clustering" of customer locations within a cluster, while remaining customer locations are located along paths extending throughout the remaining part of the cluster. Connecting cables extend from the center of the CBG to an SAI in the center of each cluster. (See Figure 5.)

b) Effective Plot Size

The average residence or business plot size per customer location is calculated by dividing the effective area of the Census Block Group (total CBG area less empty area) by the number of customer locations. The model assumes that each customer plot is twice as deep as the frontage.

A refinement to this calculation is required to account for the fact that many households occupy dwelling units that cannot be characterized as single family detached homes. Likewise, structures occupied by business establishments may range from small single-tenant stores on small lots, to high-rise buildings. Two methodologies were adopted to represent more realistically represent the actual situations that may occur:

- residential, business and joint use high rise buildings are identified by testing for situations in which the CBG size is very small, but its line

density is so high as to be incompatible with any explanation other than vertical "stacking" of the customer locations. In such cases, the model assumes the distribution cable required to serve the CBG consists of riser cable inside the high rise buildings, and that the SAI required for service is located in the basement of the building;

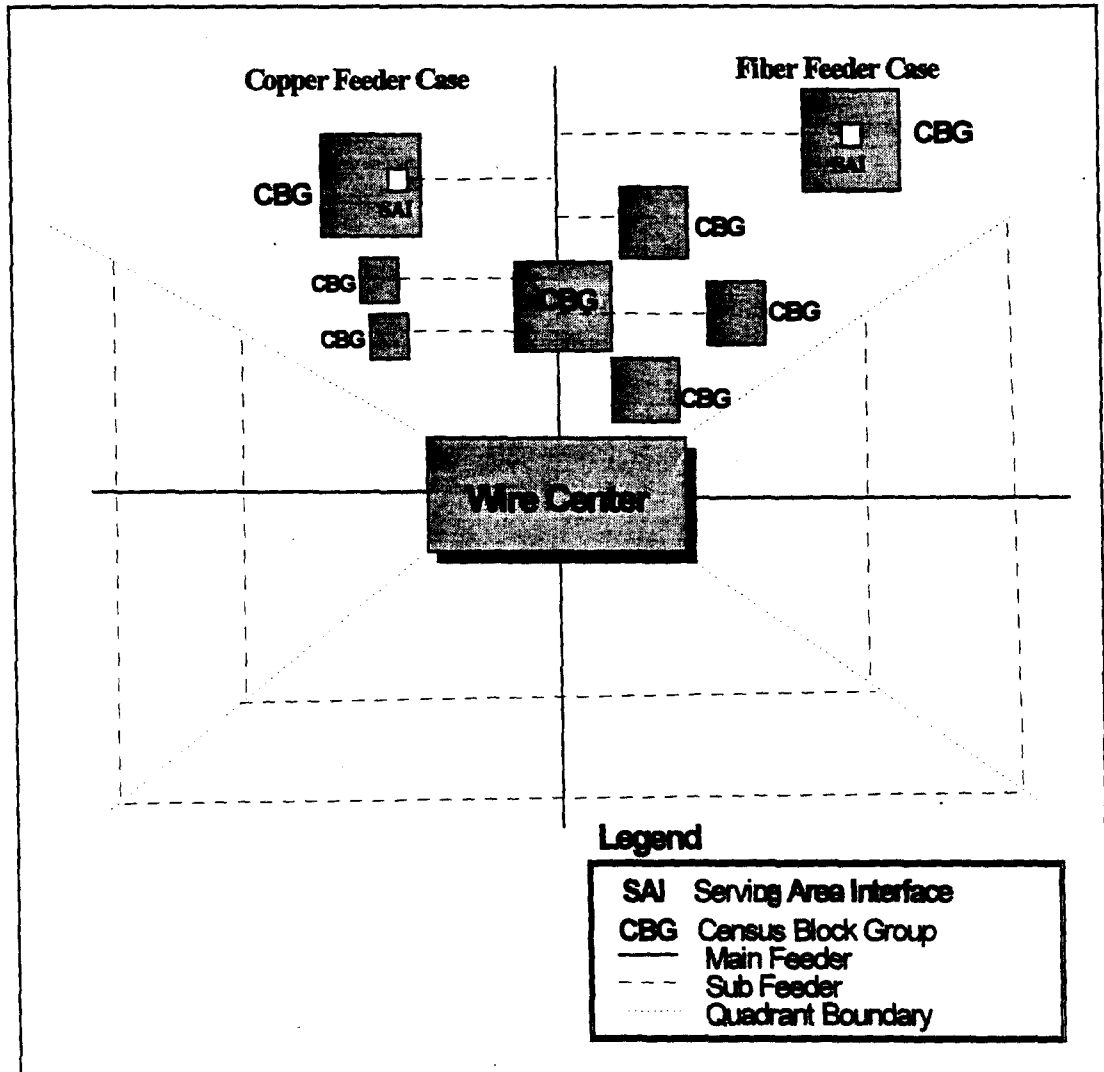
- the Census database identifies the number of households located in various types of buildings. The Hatfield Model assumes that the space occupied by residences other than single-family, detached units, is half that of detached homes, and accordingly reduces the number of customer locations, to represent more adequately the space (including the actual living quarters, shared facilities, parking lots, and other area around buildings) they occupy relative to a single home, before calculating the lot size in the manner described above. The effect, is for the model to calculate the effective lot size that detached homes would have in the CBG, and lay out the distribution grid accordingly. The model assumes the grid continues throughout the areas where multi-tenant units are located; thus, there is no additional efficiency associated with serving such premises. The assumed reduction in effective households is conservative -- the model assumes multi-tenant units represent one-half of a regular sized lot. Thus, the model is still likely to underestimate the effective lot size of detached homes because it is counting too high a number of equivalent customer locations. To limit this bias, the model places a lower limit on the minimum detached-home lot size of 1/5 acre.

Businesses are treated in a similar fashion, except that a check is made to ensure that the businesses occupy enough space to allot more than a threshold amount of square footage per employee (the PNR database estimates both the number of businesses and number of employees in each CBG). As a result, the effective lot size of the CBF, cluster or subcluster is calculated. Clusters are served by using the grid, subclusters are served by cable, and high rise structures are served by building riser cable.

## **D. FEEDER MODULE**

### **1. Overview**

Figure 6 displays the basic feeder architecture assumed in the model. Elements specific to this module are described as follows.



**Figure 6: Feeder Architecture**

As seen in Figure 1, feeder cable begins at the wire center and ends at a serving area interface (SAI) located within the CBG.

Four main feeder routes are assumed to leave the wire center. Each feeder route serves one quadrant of the wire center. Quadrant boundaries are located at  $\pm 45$  degree angles to the main feeder route. Sub-feeder cables branch from the main feeder. Sub-feeder cables extending from the main feeder route to the SAIs located within the clusters of the CBG serve all CBGs that are not directly intersected by the main feeder facilities..

The main feeder cable sizes for both fiber and copper facilities are a function of the total number of lines served in each CBG and the feeder fill factor for those CBGs. Feeder cable sizes range from 100 to 4200 pair cable for copper, and from 12 to 216 strands for fiber. Multiple cables are installed along feeder routes when the maximum size limit of a single cable is exceeded. Main feeder routes taper, i.e., diminish in size, as they pass CBGs that are served either directly or via sub-feeder. Thus, the main feeder cable sizes generally decrease in increments as the distance from the wire center increases.

Copper and fiber feeder cable may appear on a single main feeder route to serve different CBGs. If they do, they share structure, including poles, manholes, and trenching. However, cable and fiber feeder systems do not share conduit structure when they follow the same route (i.e., serve the same quadrant).

The investment in main feeder cables is allocated to individual CBGs within a wire center quadrant based on the total number of lines served in the CBG.

Fiber feeder is used where feeder lengths exceed a user-defined threshold (default 9,000 feet). Copper feeder is used for distances less than the threshold. For loop runs that exceed the fiber threshold, one of two types of DLC equipment is selected. The first is designated "TR-303 DLC" and the second is designated "Low Density DLC." The choice between them is determined for each CBG based on the number of lines in the CBG.

When a cluster is served by fiber, the sub-feeder to that CBG is assumed to have at least 12 fiber strands. The model equips more than 12 strands, if required, to serve multiple remote terminals within the cluster. For the backbone, the number of strands on each segment is determined by the requirements of all CBGs beyond that segment, taking a user-adjustable fill factor into account.

## **2. Feeder Plant Calculations**

The Hatfield Model follows four steps to compute the feeder facility investment associated with any CBG. These steps include: a) calculating main feeder and sub-feeder distances; b) sizing the copper or fiber facilities; c) computing feeder component and structure investment; and d) allocating a

fraction of the total main feeder investment to each of the served CBGs. This section describes the methodology that is used in each of these steps.

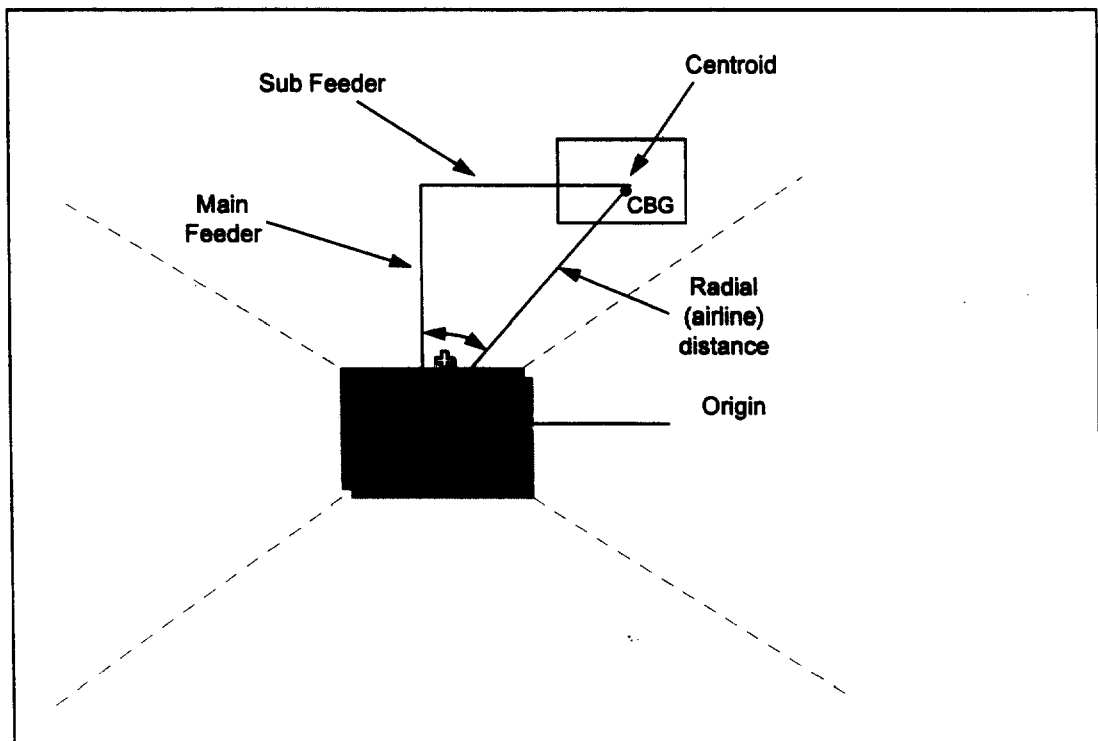
a)      **Calculating Main Feeder and Sub-Feeder Distances**

As shown in Figure 6, main feeder routes emanate from the wire center in four directions (i.e., north, south, east and west). Sub-feeder facilities branch from the main feeder at right angles, giving rise to the familiar tree topology of feeder routes. The point at which sub-feeders branch off the main feeder define main feeder segments, the portion of main feeder cable between two branch points.<sup>23</sup>

The geographic centers (centroids) of the CBGs may fall in any of the four feeder route serving areas (quadrants). The PNR database associates each CBG with a serving wire center based on the predominant wire center of the NPA-NXXS in the CBG. As shown in Figure 7, a set of parameters, including the quadrant, airline (radial) distance and angle (alpha), locates the CBG relative to the serving wire center. With this information, the Hatfield Model applies straightforward trigonometric calculations to compute main feeder and sub-feeder distances.

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<sup>23</sup> Splicing is required where the main feeder branches into sub-feeder. The cost of splicing, including material, equipment, and labor, is included in the cost of the cable assumed in the model.



**Figure 7: Trigonometric Specification of CBG Location**

The Hatfield Model selects copper or fiber feeder to serve a particular CBG according to the following method. The total main and sub-feeder distance is computed as if copper were the selected medium, (i.e., as if the SAI is located at the midpoint between the center and edge of the CBG). This distance is then compared to a user-definable fiber feeder threshold value.<sup>24</sup> If the distance exceeds the fiber feeder threshold value, fiber becomes the selected medium and the SAI is repositioned at the center of the CBG. As is evident in this methodology, it is entirely possible that main feeder routes may be comprised of both copper and fiber feeder facilities.

The computation of sub-feeder distances may vary in order to address three unique situations. The first exists when the main feeder route intersects a CBG. In this case the sub-feeder distance is zero, since no sub-feeder is needed. The second and third cases are for copper and fiber feeder; in these cases, the sub-feeder length is equal to the distance between the main feeder segment and the appropriate SAI location.

<sup>24</sup> The default threshold value is 9,000 feet.

**b1) Sizing Copper Feeder Facilities**

The model requires several inputs specifying the purchase price for copper and fiber feeder cable, as well as maximum engineered cable fill factors that vary by density range.<sup>25</sup> The default values for fill factors and cable investment per foot are as follows:

Density (lines/sq. Mi.)	Copper Feeder Fill
0 - 5	.65
5 - 100	.75
100 - 200	.80
200 - 650	.80
650 - 850	.80
850 - 2,550	.80
2,550 - 5,000	.80
5,000 - 10,000	.80
>10,000	.80

Copper Cable Size	Investment Per Foot
100	\$2.50
200	\$4.25
400	\$7.75
600	\$11.25
900	\$16.50
1,200	\$21.75
1,800	\$32.25
2,400	\$42.75
3,000	\$53.25
3,600	\$63.75
4,200	\$74.25

<sup>25</sup> Cable costs include the cost of materials plus engineering, delivery and installation. Installation does not include structure. For example, these numbers include the cost of attaching cable to a pole, but do not include the cost of the pole itself.

Fiber Cable Size	Investment Per Foot
12	\$2.90
18	\$3.20
24	\$3.50
36	\$4.10
48	\$4.70
60	\$5.30
72	\$5.90
96	\$7.10
144	\$9.50
216	\$13.10

#### b2) Copper and Fiber Sub-Feeder Cable Sizing

Sizing copper sub-feeder cable for individual CBGs is a function of two parameters: the total number of lines served within the CBG and the copper feeder fill factor. To select the appropriate cable size, the required line capacity is computed by dividing the total number of lines in the CBG by the fill factor. The model then chooses the smallest cable size that meets or exceeds the increased line count. For instance, if the number of lines is 200 and the fill factor is .80, the next cable size larger than  $200/.80$  is selected. Since  $200/.80$  equals 250, the 400 pair cable is selected. This lowers substantially the average actual fill compared to the input value entered. Multiple cables are used in cases where the maximum cable size is surpassed.

The number of optical fibers needed to serve a given CBG is a function of the total number of lines served within the CBG, the line capacity of the DLC system and the loop carrier system fill factor.<sup>26</sup> Using these parameters, the Hatfield Model computes the total number of DLC remote terminals that are required to serve all the lines in the CBG. Four fiber strands are then assigned to each DLC remote terminal.<sup>27</sup> The model then chooses the

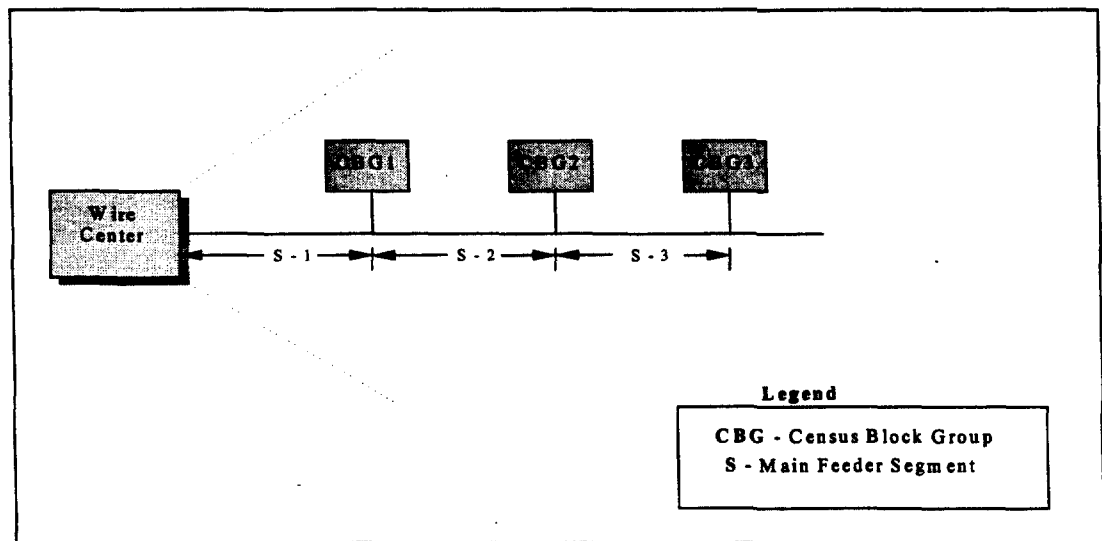
<sup>26</sup> The DLC default values used in the Hatfield Model are as follows: TR-303 DLC, 672 lines per remote terminal and 90 percent fill; Low Density DLC, 96 lines per remote terminal and 90 percent fill.

<sup>27</sup> The number of fiber strands required per DLC remote terminal may be set by the user; four strands is the Hatfield Model default value. The DLC terminal requires a minimum of two fibers -- one for each direction of transmission -- the Hatfield default specifies an additional two for complete redundancy.

smallest optical fiber cable size that meets or exceeds the required number of strands. The minimum cable size serving any one CBG contains twelve fiber strands. The process for sizing fiber cables is the same for TR-303 DLC or Low Density DLC.

### b3) Main Feeder Segment Sizing

Figure 7 demonstrates that multiple CBGs share capacity on certain segments of the main feeder route. Segments located closer to the wire center require more capacity than segments near the periphery. The Hatfield Model addresses this situation by tapering the main feeder facilities as the distance from the wire center increases. Thus, each segment in the main feeder is sized to serve all the CBGs located past the segment. For example, in Figure 8, segment 1 is sized with adequate capacity to serve CBG1, CBG2 and CBG3. Segment 3 will be sized with less capacity than segment 1 since it serves only CBG3.



**Figure 8: Main Feeder Segmentation**

Sizing the cables along each segment of the main feeder route is based on individual CBG cable sizes, options and the locations of the CBGs along the main feeder route. The individual cable requirements for CBGs at and beyond the end of a particular main feeder segment are aggregated to determine the required cable size for that main feeder segment. When the maximum cable size is exceeded on a given segment, multiple cables are installed.

c) Computing Feeder Component and Structure Investment.

Feeder facilities consisting of copper or fiber cable provide a link between the wire center and SAIs located within each CBG cluster. The SAIs in each CBG serve as an interface between the feeder and distribution facilities. It consists of a cabinet, including suitable physical mounting, and a simple passive cross connect in the case of copper feeder, or optical multiplexers, optical to electrical converters, digital codecs, and cross connects in the case of optical feeder. SAI costs are dictated by the number and size of distribution cables emanating from the interface. Larger cables lead to larger SAIs, which, in turn, lead to increased SAI investment.

The electronic components that are collocated with fiber feeder SAIs are digital loop carrier (DLC) remote terminals. The Hatfield model will select one of two types of DLC equipment for each CBG based on the number of lines. The first is designated "Low Density DLC" and the second is "TR-303 DLC." Investment in DLC equipment is dependent upon several user-definable parameters, including site installation and power investments, common equipment investments, and channel unit investment.

The fraction of aerial, buried and underground plant may be set for all density ranges and for each feeder cable type, copper or optical fiber. The Hatfield Model default values for these parameters appear in the following table:

**Copper Feeder Type Breakdown**

Density Range	Aerial Fraction	Buried Fraction	Underground Fraction
0 - 5	.50	.45	.05
5 - 100	.50	.45	.05
100 - 200	.50	.45	.05
200 - 650	.40	.40	.20
650 - 850	.30	.30	.40
850 - 2,550	.20	.20	.60
2,550 - 5,000	.15	.10	.75
5,000 - 10,000	.10	.05	.85
>10,000	.05	.05	.90

**Fiber Feeder Type Breakdown**

Density Range	Aerial Fraction	Buried Fraction	Underground Fraction
0 - 5	.35	.60	.05
5 - 100	.35	.60	.05
100 - 200	.35	.60	.05
200 - 650	.20	.60	.20
2,550 - 5,000	.15	.10	.75
5,000 - 10,000	.10	.05	.85
>10,000	.05	.05	.90

Urban areas normally have feeder cable running directly into the basement of large buildings, rather than interfacing at an SAI outside of the building. In such cases, the SAI involves "punch down blocks" in the basement of the building. This type of interface consists of a plywood backboard and inexpensive punch down blocks, rather than the heavy steel weatherproof outside terminals found in more suburban and rural areas.

In addition to the sharing of structure between telephone companies and other utilities, there are two other forms of structure sharing relevant to feeder plant. First, with the exception of conduit, structure is shared between copper and fiber feeder cables along main feeder routes. A detailed discussion of the sharing of structure between feeder and interoffice facilities is presented in the interoffice section of this document.

d) Allocating a Fraction of Total Main Feeder Investment to CBG

All the feeder facility investments are computed on a per CBG basis. To do this, it is necessary to assign the appropriate amount of investment in each main feeder route to the individual CBGs that are served by that route. The portion of the main feeder investment assigned to a CBG is computed using the ratio of lines in each CBG to total number of lines in the quadrant. This is done separately for the copper and fiber feeder that may coexist on a given route.

## **E. SWITCHING AND INTEROFFICE MODULE**

### **1. Overview**

This Module produces network investment estimates in the following categories:

*Switching and wire center investment* -- This category includes investment in local and tandem switches, along with associated investments in wire center facilities, including buildings, land, power systems and distributing frames.

*Signaling network investment* -- This includes investment in STPs, SCPs and signaling links.

*Transport investment* -- This category consists of investment in transmission systems supporting local interoffice (tandem and direct) trunks, intraLATA toll trunks (tandem and direct) and access trunks (tandem and dedicated).

*Operator Systems investment* -- This includes investments in operator systems positions and operator tandems.

### **2. Description of inputs and assumptions**

For the Switching and Interoffice Module to compute required switching and transmission investments, it must have as inputs total line counts for each wire center, distances between switches, traffic peakedness assumptions, as well as inputs describing the distribution of total traffic among local intraoffice, local interoffice, intraLATA toll, interexchange access and operator services. This module takes as data inputs overall line counts obtained from the PNR database for the CBGs belonging to that wire center, and interoffice distances for the calculation of transmission facilities investments.<sup>28</sup>

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<sup>28</sup> HM R3.0 includes a set of interoffice distance calculations produced from wire center location information from Bellcore's Local Exchange Routing Guide (LERG).